SEMI-ANNUAL STATUS REPORT

NASA Grant NsG 426

(California Institute of Technology)

1 April 65 - 30 Sept 65

The present report covers the first half of the third year of operation under NASA Grant NsG 426. As in previous status reports, this report is divided into a number of sections which describe the activities of the more-or-less separate groups sponsored by this Grant, followed by an over-all summary of staff, expenditures, and bibliography.

For the benefit of the reader who may not be interested in technical detail, the following brief summary will provide a general picture of the activities of the various groups.

SUMMARY

I. Cosmic Rays (Neher)

Dr. Neher's activity under this Grant is principally directed towards the manufacture and field operation of a number of his very accurate absolute ionization chambers. Some of these have been completed and flown to balloon altitudes from Thule, Greenland.

During the summer of 1965 a total of 34 balloon flights were made to study the geomagnetic effects on the primary cosmic radiation during the present quiet period of the sun. Half of these flights were made from a mobile station while en route from Peru to Thule, Greenland. The other half were made at the same Greenwich time from Bismarck North Dakota, the purpose being to monitor the primary radiation.

Another part of this program, being carried out jointly with JPL, has consisted of readying instruments to go on POGO. This polar orbiting satellite is scheduled to be launched during October of 1965. All components for the experiment were functioning properly at the time of this report.

II. Cosmic Rays (Vogt and Stone)

Drs. Vogt and Stone are engaged in a research program directed towards the investigation of the astrophysical aspects of cosmic radiation and the radiation environment of the earth. This investigation is carried on by means of particle detector systems flown on spacecraft and from balloons. This group is presently using balloon and satellite-borne particle detector systems to study astrophysical and geophysical aspects of cosmic radiation. The main efforts of the laboratory have been directed towards the following three experiments:

1. A satellite experiment is to be flown on the OGO-C and D spacecraft, the first of which is scheduled to be launched during fall 1965. This experiment, which is being carried out jointly by Dr. Stone at Caltech and Drs. J.A. Simpson and C.Y. Fan at the University of Chicago, will measure the time-dependent energy spectrum of protons between 0.7 MeV and 40 MeV, and of alpha particles between 2 MeV and 160 MeV. The experiment should provide valuable information on the mechanism of acceleration of high-energy particles in solar flares and the propagation of those particles to the earth. In addition, study of the cut-off momenta as functions of spacecraft location and time should add to the understanding of the earth's magnetosphere.

2. A balloon-borne version of a proposed satellite experiment, which was flown from Ft. Churchill, Manitoba, during summer 1965. Two complete flight gondolas were constructed. Each contained detector systems designed to measure the differential energy spectra of protons and alpha particles between 700 keV and 1 GeV per nucleon, and of electrons between 100 MeV and 1 GeV. The experiment has similar scientific objectives to the above, except that it significantly extends the range of energies measured.

3. A balloon-borne experiment which will involve the first use of the newly developed digitized spark chamber techniques. The first experiment will be a high-energy electron spectrometer for use in the energy range from 100 MeV to several GeV. The instrument will be flown during the summer of 1966.

III. Theoretical Aspects (Christy)

For the past several years Dr. Christy has pursued a fundamental investigation of the mechanisms of instability of pulsating variable stars such as the cepheids and the RR Lyrae variables. With the help of an IBM 7094 computer he has succeeded in working out the systematics of the instabilities of the RR Lyrae stars, and has extrapolated these results to the cepheid variables. A major paper describing this work is soon to be published in the Astrophysical Journal.

IV. Interplanetary Magnetic Fields and Plasmas (Davis, Haerendel and Siscoe)

This group, including associated graduate students, is engaged in the interpretation of observations and theoretical studies on the interplanetary magnetic field and plasma, and their interaction with planets and their moons. This includes studies, where appropriate, of cosmic rays and energetic particles.

A major activity has been the preparation of computer programs for the reduction to convenient form and the preliminary analysis of the Mariner IV Magnetometer Master Data Tapes. It is hoped that a substantial amount of data will be available from JPL for analysis in this way soon. Preliminary Mariner IV Data has been studied in collaboration with the other magnetometer experimenters and it has been found that
1) the intrinsic magnetic moment of Mars is very small and perhaps is zero; (2) the expected spiral pattern of the interplanetery field is present on the average but the polarity pattern, which must be governed by the polarity pattern in the solar corona, changes slowly with time; (3) the earth's bow shock either moves back and forth leading to multiple transitions or has a complicated structure; (4) during some intervals, the power spectra in the transition region indicates significant changes in field strength with periods around 4 minutes.

Other investigations undertaken during this period include studies of the acceleration of electrons outside the earth's bow shock, the diffusion of energetic charged particles in the magnetosphere when the second adiabatic invariant is violated, the interaction of the solar wind with the Martian atmosphere, and the effect of electric currents in the magnetospheric tail of the earth on geomagnetic disturbances and storms.

V. Infrared Astronomy (Neugebauer, Leighton and Ulrich)

This group is engaged in astrophysical observational studies in the infrared spectral range. Up until the present time the investigations have been ground-based, utilizing the several available atmospheric "windows". The principal objective at present is the completion of a survey of the sky in two infrared spectral wavelength ranges, 0.7 - 1.0 microns, and 2.0 - 2.5 microns. The survey instrument consists of a 62 inch, f/1 plastic paraboloidal mirror capable of 2' arc resolution with a liquid nitrogen cooled detector array at its principal focus. This infrared telescope is situated on Mount Wilson and is operated almost every clear night.

Other activities of the group include:

1. Multi-band photometric measurements of the infrared intensities of unusual infrared sources found in the sky survey.
2. Preparation of a liquid hydrogen cooled, mercury-doped germanium detector array for survey use at 8-13 micron wavelength.
3. Construction of a special lead sulfide detector system (utilizing infrared polaroid) to test sources for linear polarization in the 2.0 - 2.5 micron range, and
4. Application of an existing infrared spectrometer (on loan from JPL) to spectral distribution measurements of various objects at the Mount Wilson 60 inch or 100 inch telescopes.

VI. Planetary Spectroscopy (Münch, Neugebauer, and Ridgeway)

For several years Dr. Münch of the Mount Wilson and Palomar Observatories has been engaged in a study of the high-dispersion spectra of the planets, particularly Mars, Jupiter, and Saturn. It was principally from measurements obtained by him and his colleagues that the low value now accepted for the surface atmospheric pressure of Mars was first derived. Because of the difficulty of this measurement and its importance in the study of Mars by space probes, especially Martian landers, many people are attempting to improve upon the existing measurements. Recently, Drs. Münch and Neugebauer have endeavored to measure the Martian atmospheric parameters using certain carbon dioxide bands in the 2-micron wavelength range. These measurements are now being reduced.

VII Instrumental Development (Dennison, Rule, and Oke)

An activity of a somewhat different nature from the others is that of the instrumental development group, whose operations are partially supported under the NASA Grant. What this group does is not, in itself, pure astrophysical research, but its activities are among the most important being carried on at the Mount Wilson and Palomar Observatories in terms of the eventual yield of new astrophysical results.

Its major concern is to assure that the major telescopes are adequately coupled with the proper up-to-date accessory instruments such as spectrographs, photometers, spectrum scanners, data handling systems, etc., so as to assure their utmost utility and efficiency for the widest variety.

Among the major activities of this group during the report period have been the following:

a) The design and construction of an observers cage for the 200-inch Hale telescope. This cage will attach to the lower end of the main telescope tube, and will permit a considerable amount of heavy electronic equipment to be mounted conveniently close to the Cassegrain focus.

b) The engineering and optical design of an efficient image-tube nebular spectrograph. This instrument is urgently needed in the study of such things as the quasars, which are among the most luminous and distant known objects in the universe.

c) The development of a modern, digitized data acquisition system for the major telescopes.

d) Improvement of the Coudé spectrum scanner of the 100-inch telescope, by the introduction of a versatile, all-digital control system with photon counters and digital readout. This instrument is now used approximately 50 percent of the time and has greatly accelerated and simplified spectral scanning work at the 100-inch telescope.

FURTHER DESCRIPTION OF ACTIVITIES

Cosmic Rays (H.V. Neher)

To continue the program of studying the geomagnetic effects on the primary cosmic radiation, a latitude survey was carried out in the summer of 1965 using the instruments that were described in earlier reports. This survey was planned to coincide with the period of maximum cosmic ray intensity for the present solar cycle. Actually, the maximum seems to have occurred in April or May of 1965 but the intensity was not down more than a few percent at high altitudes and latitudes when the survey was made in July 1965.

With the co-operation of ONR, arrangements were made to transport the gear by ship to Peru. Two people launched 17 flights at regularly spaced latitudes from commercial ships (Lima - New York) and a naval ship (New York - Thule), from below the geomagnetic equator to near the north geomagnetic pole. Of the 17 flights, 15 were satisfactory. In the two cases where there was a failure, another flight was made immediately, so that successful flights were made at all the latitudes at which data were desired. Simultaneously with those launched from shipboard, similar instruments were launched from Bismarck, North Dakota. This monitoring of cosmic rays permits corrections to be made for day-to-day changes in the radiation and the true geomagnetic effects can thus be separated out.

Another part of this cosmic ray program which has been carried out in collaboration with Dr. Hugh R. Anderson at JPL, is the preparation of instruments for POGO. The first of these is scheduled to be launched on 14 October, 1965. The instrument, an ionization chamber that is intercalibrated with the balloon instruments described above, appears to be operating satisfactorily on all the tests at the time this report was written.

A joint paper with H.R. Anderson of JPL entitled, "Cosmic-ray Changes During a Solar Cycle", was presented at the September 1965 meeting of the cosmic-ray section of the International Union of Pure and Applied Physics. Among other items considered, this paper presented some results from Mariners II and IV and their relationship to similar data taken near the top of the atmosphere near the north geomagnetic pole. The paper will appear in the conference proceedings.

II. Cosmic Rays (R. Vogt and E.C. Stone)

The three experiments mentioned in the summary are here described in more detail.

OGO-C and D Experiment

Some of the studies resulting from the OGO-C experiment will be undertaken at Caltech. Preparation for these studies are as follows:

a) A study of the electron sensitivity of thin silicon semiconductor detectors has been made using experimental data obtained elsewhere. This sensitivity to electrons with energies $\gtrsim 0.4$ MeV, although small, sets a lower limit on the minimum detectable proton flux. It is planned to supplement these calculations with further measurements at Caltech.

b) The calibration data for the experiment flight unit have been reduced to a computer-compatible form for use in reducing and analyzing flight data.

c) Alogorithms for efficiently and economically reducing satellite data in terms of relevant magnetic and spatial co-ordinate systems have been developed by detailed study of the predicted OGO-C orbit.

d) The initial processing and presentation of the flight data have been specified, and both students and professional programmers at CIT's computing center are preparing programs.

Although the OGO-C data processing and analysis are now funded separately, the resulting OGO-C studies are an integral part of the group's research effort as supported by this grant.

The p, α, e Balloon-Borne Experiment

This instrument consists of two counter telescopes. The 0.7 to 300 MeV/nucleon spectra are measured by a dE/dx-range system composed of one-surface-barrier solid state detector (100μ thick, 2.5 cm^2

sensitive area with guard ring) and six lithium-drift detectors (1000μ depletion depths, 4.5 cm^2 with guard ring) separated by tungsten absorbers. The spectra above 350 MeV/nucleon are measured by a dE/dx - Čerenkov system composed of a lithium-drift detector and a lucite Č-radiator.

The construction and testing of two flight gondolas and the ground support equipment was completed by June 1965. This phase of the experiment involved almost all of the group's effort and facilities for about six months. Some of the activities during this interval included:

1) Calibration of solid state detectors, lucite Č counters, and plastic scintillator anti-coincidence counters on the CIT synchrotron. Special attention was given to the Č counter, since good directionality was important. A front-to-back ratio of $> \frac{25}{1}$ with typical resolutions of 35% FWHM were achieved.

2) The integrated detector systems performed properly during cosmic ray μ-meson runs. Extended calibrations on various particle accelerators were planned for the post-expedition period.

3) A portable readout system was built for converting magnetic flight tapes to paper tapes in the field.

4) The 14-station automatic battery charger for Ag-Zn type cells was completed and tested prior to the expedition.

The summer balloon flights at Ft. Churchill, Manitoba, were conducted as part of Project Skyhook '65, under the direction of ONR. (O. Winzen, flight contractor). Four members of the group were in the field for nine weeks, during which time further testing and calibrations were performed on the equipment. A defect in the contact design of the solid state detectors supplied by Solid State Radiations, Inc., was discovered in the aging of the detectors. This defect was eliminated by replacing the mechanical contact by an epoxied contact. In every other respect, the equipment performed completely satisfactorily.

A total of four balloon launches were attempted. The first flight was only partially successful in that ballast was not dropped and a faulty experiment connector shorted out 2 of the 16 channels on the flight tape recorder. The loss of these two channels does not affect rate information or crude spectral analysis, but it does prevent the detailed analysis necessary for definitive spectral determination.

The second flight was a total loss due to the failure of the Winzen cutdown equipment. It is likely that the gondola drifted over the Pacific Ocean.

The third launch was terminated when the Winzen cutdown equipment fired five feet above the ground. The flight gondola suffered minor mechanical damage which was repaired in the field.

The fourth launch led to the loss of the second, and last, flight gondola, again due to multiple failures in the Winzen balloon-support electronics. Cutdown was accomplished, but the lack of a radio beacon antenna (which was lost at launch) prevented the search planes from tracking down the load. An ensuing search led to the recovery of the balloon. However, due to the termination of Skyhook '65, the search was discontinued before the gondola could be found.

These losses were not unavoidable, but were the result of the inexperience and unsatisfactory instrumentation of the Winzen Company, which had been chosen by ONR for Skyhook '65. A more detailed report, including suggested improvements in the operation of such balloon programs, will be submitted to ONR and NASA.

The total loss of the p, α, e gondolas is especially unfortunate, since they represented a prototype instrument for the proposed CIT OGO-F experiment. They were to be used for further calibrations and for testing of modifications and new ideas prior to the construction of the satellite experiment.

The High-Energy Electron Spectrometer

The electron spectrometer under construction is designed to measure the energy spectrum of electrons between ~ 25 MeV and several GeV. The system will also be capable of measuring proton and alpha spectra from ~ 75 - 200 MeV/nucleon, and will allow the investigation of the effect of nuclear interactions in Pb upon the range-energy properties of these particles. The detector system consists of a combination of scintillation counters, a gas Čerenkov counter and a digitized spark chamber separated by lead absorbers.

Main objectives of the planned balloon observations are studies of the electron content of galactic and solar particles and the properties of the earth's electron albedo.

Development and testing of the digitized spark chambers discussed in an earlier report have continued. Since ultimately we intend to use these chambers in satellites, special efforts are being made to produce clean chambers (i.e., ceramic materials) which can be operated sealed over long periods. Frequent exposures to the electron beam of the CIT synchrotron are made in efforts to test modifications leading to reduced spark spreading and increased multi-spark efficiency, which at the present stage of spark chamber technology are still common problems.

Radio frequency shielding techniques which will allow the operation of spark chambers in the presence of other sensitive electronic equipment have been developed and tested. While our spark chamber development in the past was mainly done with conventional laboratory type equipment, the major part of the equivalent flight circuits have now been designed and tested. Among those are new readout circuits for magnetic memory cores, sense amplifiers, fast scalers and shift registers. The flight version of a fast triggered high voltage pulser for the spark chamber is now in operation. It uses a combination of an avalance transistor and a Krytron (cold cathode) to trigger a spark gap and has low power consumption.

A complete ground support station with a fast teletype printout has been built and is operating. It is used both for ground tests and calibration readouts of the chambers and for conversion of the gondola's magnetic flight tapes into computer compatible paper tape.

Construction of the flight electronics on plug-in cards is under way.

The previously designed gas Čerenkov counter has been built and tested on the synchrotron. It is working satisfactorily and presently gives a 95 percent detection efficiency. The final flight version of the Čerenkov counter is presently being tested.

III. Theoretical Astrophysics (R.F. Christy)

The work of the last several years has now been written up in a paper entitled "A Study of Pulsation in RR Lyrae Models", recently accepted for publication in the Astrophysical Journal. Copies of a preprint of this work have been submitted to NASA.

During the summer, three separate presentations on this subject were made: an invited paper at an International Astronomical Union Colloquiumat Bamberg, Germany, on variable stars was presented on August 12. From August 15 to September 1, the author was one of a number of invited lecturers at a NATO-sponsored summer school at Herstmonceux England. Several lectures on variable stars were presented. From September 1 to September 15, the author attended the Fifth Symposium on Cosmical Gas Dynamics at Nice, France, sponsored by the IAU. An invited paper was presented on the subject of pulsation. The proceedings of the Bamberg conference and of the Nice Symposium will be published.

Future plans involve the continued exploration of the boundaries of instability for Cepheid and related variable stars. In addition, the possibility of treating free convection in stars is being studied.

IV. Interplanetary Magnetic Fields and Plasmas (L. Davis, Jr., G. Haerendel and G.L. Siscoe)

The computer programs described in the summary will check the Magnetometer Master Data Tapes supplied by JPL for gaps and bad data, will convert the good data from arbitrary digital form to vector magnetic fields described in solar polar co-ordinates, will compute averages and variances over a series of intervals, and will list the number of each of several patterns of fluctuations. Among other things, this should enable us to present in convenient form the average structure of the field and some idea of its fluctuations over periods ranging from a few seconds to 27 days. This work is being carried out for the benefit of all the Mariner IV Magnetometer Experimenters, including those at other institutions.

Dr. G.L. Siscoe and Mr. D.H. Griffel are investigating the interaction of the solar wind with the Martian atmosphere. The

V. Infrared Astronomy (G. Neugebauer, R.B. Leighton, B.T. Ulrich)

The program of the infrared astronomy group during the report period entered a new phase with the completion of the construction of the sky survey instrumentation at Mt. Wilson, and of the building up of the laboratory facilities at Caltech. In addition, the report of the existence of extremely cool sources in Cygnus and Taurus (Neugebauer, Martz, Leighton, Ap. J. 1965, 142, 399) has led to an accentuated interest in more detailed studies of these stars.

The sky survey for sources emitting strongly between 2.0 and 2.5μ was continued in the manner described in previous status reports. Since the equipment was fully operational only minor improvements and routine maintenance on the equipment were necessary. During the 6 month period in question the nights were divided up roughly as follows:

2.0 - 2.5μ survey	90 nights
Survey standard star calibration measurements	9
10μ survey and check out (see below)	13 1/2
Red star location - partly cloudy (see below)	6 1/2
Red star photometry (see below)	3 1/2
Polarization studies (see below)	4
Clouded out	53 1/2

Only one and one half nights were lost due to equipment failure. Survey data covering approximately three fourths of the visible sky have been obtained.

The program for automatically reducing the survey data has been pursued under the direction of Dr. Ulrich. Data recorded on strip charts at the telescope are now being digitized on a daily basis. The digitized data are treated on the 7090 computer to correlate observed peaks into stars, make preliminary co-ordinate corrections, and to reduce peak heights to magnitudes. Refined estimates of co-ordinates are made by combining the data from several cells. The programs for correlating several nights data have been blocked out and are now being written. Finally, bright stars found in the survey are identified in a catalog of known stars to correct for possible systematic errors in stellar co-ordinates.

Unfortunately, several subtle problems were encountered which have delayed this program. Any given source is observed at least three times with the survey instrument and sometimes as often as eight; one primary difficulty with the automated program is the correct identification of the multiple peaks observed from one source as really having come from a single source rather than from two closely spaced sources. At the present time the program identifies peaks correctly in about 95 percent of the cases; mistaken identifications come mainly from extremely weak or strong sources.

An appreciable amount of non-direct survey work was also carried out using the 62" telescope. A visual search of the survey strip-chart records was made for stars which exceed definite redness and brightness criteria and which seem to be worthy objects for further study. These are being observed on a regular program to check for long time effects such as variability. Partly cloudy nights which were not suited for normal survey work have been utilized to refine the co-ordinate identifications of these sources.

The 8-14 micron dewar, designed to look for a source or sources near the galactic center, was finished and put into operation. The detecting elements are eight mercury-doped germanium cells similar in size and arrangement to the PbS cells used in the 2.0 - 2.5μ survey. The sensitivity of the system has been severely limited by background radiation which fluctuates randomly with a time scale on the order of 1 sec. Changes in the size of these fluctuations from night to night, within the same night, and from one part of the sky to another point to the conclusion that this background comes from real changes in the atmosphere. By selecting especially good nights, it was possible to survey the region of the galactic center, but no discrete source was found. The search is being continued.

During the summer a special dewar was constructed which contains a rotating infrared polaroid filter in order to study the polarization in the 2.0 - 2.5μ region. Preliminary results indicate that the extremely cool source found in Cygnus may have as much as 5 percent polarization.

Other telescopes as well as the 62" have also been used by the group. The photometry begun by Becklin on the 60" Mt. Wilson telescope has been continued with special emphasis on high spatial resolution scans of the Orion and Crab nebula using selected narrow-band wavelength filters between 2.0 and 2.5µ. In addition, photometric measures at several wavelengths on about 15 nebulae and galaxies have been obtained.

The 48" Schmidt camera at Palomar has also been used with red-sensitive 1N plates primarily in order to help identify peaks recorded by the survey in the more crowded regions of the sky. A by-product obtained from these plates has been that upper limits can be placed on the proper motion of the source in Cygnus which indicate it is probably a very distant source.

A preliminary spectroscopic study of the extremely red sources has also been initiated in order to explore the utility of 60 - 200 Å resolution spectroscopy around 2µ. The spectrometer is a 50 cm Ebert-Fastie type borrowed from JPL and adapted by members of the group for telescope use. Spectra of about 20 sources of various temperatures have been obtained in 1.3 - 1.8µ, 2.0 - 2.5µ, and 3 - 4µ. Although most features are dominated by the absorption in the earth's atmosphere, several stellar features have been observed. Computerized data reduction is now underway.

VI. Planetary Spectroscopy (G. Münch, G. Neugebauer and S. Ridgway)

a) Spectral observations of Mars

The unusually poor observing conditinns prevailing last spring at Mount Wilson considerably curtailed the plans of Drs. Münch and Neugebauer for their Mars observation. In order to be certain that some measurements of the weak CO_2 absorption lines were obtained, it was decided when the opposition was past to concentrate the effort on the proven photographic method. A total of eight plates covering the $5\nu_3$ band at λ8690 A were secured. The dispersion used was 3.3 A/mm, compared to the 5.4 A/mm used during the 1962 opposition. The measurements of the equivalent widths of the R8, R10, and R12 lines in the two plates with best definition and density give a mean value of $W = 0.0018 \text{ cm}^{-1}$, with an uncertainty estimated at thirty percent, for an effective Martian air mass of 3.1. This value is in essential agreement with the 1962 result as it implies a CO_2 content of 57 meter-atm.

The reduction of the data obtained for the strong $4\nu_2 + \nu_3$ band at λ3.06μ has been continued. In the preliminary analysis of the ratio R between intensity maxima and minima in the observed rotational structure of the band, Dr. Münch and Neugebauer found a steeper dependence of R on terrestrial air mass in Mars than in the moon. This discrepancy has not been explained either by a reasonable temperature difference between Mars and the Earth, or by taking into account the absorption by possible minor constituents in the Martian atmosphere, such as $C^{12}C^{13}O_2$ or H_2O. Since the interpretation of the data cannot be considered satisfactory until the discrepancy is explained, a more detailed calculation of the profiles in the entire rotational structure, rather than only the maxima and minima, has been undertaken. Disregarding the unexplained effect, on the basis of the preliminary analysis of the strong 2.06μ band and the measurements of the weak $5\nu_3$ band referred to above, a value of 19 mb has been estimated for the pressure at the surface of Mars.

b) <u>Magnetic Spectrometer</u>

The magnetic resonance spectrometer developed by Drs. Ridgway and Münch has now been tested in the laboratory and its efficiency measured by observing the sun. By illuminating a sodium resonance cell placed between the poles of a permanent magnet and directing the resonantly scattered light into the analyzing cell of the spectrometer through suitable polarizers, it has been verified that the resolving power of the instrument is about 10^6, as expected from the Doppler thermal width of the metal vapor in the analyzing cell. The experiment with the solar light was carried out in the Hale solar tower. By comparing the output of the multiplier with the known incident solar flux, it has been estimated that the efficiency of the whole system is about 1/700, which number includes reflection losses at the telescope, interference filter and collecting optics, besides the solid angle factor. From the experience acquired in the construction of the instrument, it appears that its efficiency cannot be increased without going into a much more elaborate system for collecting the resonantly scattered radiation. One could use, for example, a whole battery of photomultipliers surrounding the scattering cell to increase the solid angle accessible to detection. The complication may well be worth it if one wished to exploit the properties of a magnetic spectrometer as an analyzer for polarized radiation. Such an instrument is the only high resolution spectrometer which can be used as part of a completely symmetric optical system, and therefore does not introduce spurious polarization in skew reflections. For observations of the transverse Zeeman effect produced in solar magnetic fields, it would be ideal if used with a symmetric solar telescope, as a Cassegrain. Considering that we do not have available such a telescope, the unique property of the magnetic resonance spectrometer as an analyzer cannot be fully exploited at present. An attempt to observe solar magnetic fields would have to be made using a cell or atomic beam of calcium, strontium or barium elements with a $^1S_0$ ground state, as published recently in detail by Roddier (Annales d'Astrophysique, Vol. 28, p. 463, 1965), are in essential agreement with our conclusions regarding the low efficiency of the instrument. Considering the limited use that can be made of a magnetic scanning spectrometer for planetary or stellar work, and the encouraging results so far obtained with Fabry-Perot interferometers (Section c, below), Drs. Ridgway and Münch have decided to redirect their efforts to increase the spectral resolving power of large spectrometers by means of Fabry-Perot etalons, which are advantageous because of their versatility if they can be incorporated into a stable and easily adjustable system.

c) <u>Coudé photoelectric spectrum scanner and interferometer</u>

The adaptation of a Fabry-Perot etalon to the photoelectric spectrum scanner of the coudé spectrograph of the 100-inch Mount Wilson telescope has been further developed by Dr. Munch in collaboration with Dr. A. Vaughn of the Mount Wilson Observatory Staff. Because of the narrowness of interstellar lines, it was decided to start by observing the D-lines of Na I, for which very high resolution observations in a few stars have been made photographically by Lynds and Livingston with the McMath solar tower and in α Cygni by Hobbs with a PEPSIOS system of three stacked Fabry-Perot etalons. At present, we use flats of 1/100 accuracy, mounted in a cell with ball-bearings as spacers. The transmission of the Fabry-Perot cavity is varied by changing the air pressure in suitable steps as the grating spectrum is scanned. With a FW130 photomultiplier as detector, one interstellar D-line in a star of visual magnitude 5 can be scanned in two hours with a resolution of 0.03 A. This represents a gain in time of about ten over the photographic plate used in the same spectrograph. A paper containing the preliminary survey of the interstellar lines carried out with the interferometer has been prepared. It has been found, however, that in its present form the interferometer has to be readjusted and calibrated often, as consequence of temperature changes. It is planned, therefore, to introduce thermostatic temperature control and an automatic system for changing the transmission in phase with the grating scan.

VI. Instrument Development (Dennison, Oke, Rule)

200-inch Cassegrain Cage and Nebular Spectrograph

During the last six months one major mechanical development for the 200-inch telescope has been the design and construction of a Cassegrain Cage. The purpose of this cage is to provide adequate space for the rather bulky new instruments which are needed and for the elaborate electronics associated with them. The prime focus cage is unsuitable for such instruments because it allows space for instruments with dimensions of at most 20 to 24 inches. At the Cassegrain, instruments several times this size can be installed and operated efficiently. The Cassegrain cage structural assembly is nearing completion at the Palomar Observatory shops and will be completed in a few weeks. The Cassegrain observer's chair, which permits the astronomer to work moderately comfortably for any position of the telescope and with any orientation of the Cassegrain instrument being used, has been completed in the Caltech Engineering shops and is ready for installation. A temporary control system will be provided for initial use at the Cassegrain until the final cable windup and observing auxiliaries are determined.

The first major instrument for the Cassegrain will be an efficient image-tube nebular spectrograph. The arrangement and optical design, by Bowen, has been agreed upon and engineering designs and shop work are now proceeding rapidly with particular emphasis on the long-lead items such as castings, optical parts, etc. Among the most important parts of an instrument such as the nebular spectrograph are the mechanisms for rotation of the instrument on the telescope, direct guiding, off-set guiding, finding of objects, etc. All these components require very accurate machining and assembly. For convenience this is being designed as a complete unit on which the spectrograph, and other instruments can be attached. This system has been almost completely designed and construction will proceed immediately.

The other major development program for the 200-inch is the design and construction of a modern data-acquisition system for recording data from the various electronic instruments on the telescope. The room for both control and data collection has been completed, using observatory funds, and some equipment has already been installed and in use for some months. A remote telescope-control desk for this room, also being done on the Observatory account, is nearing completion. Rapid progress is being made in the data acquisition system to be installed in this room and on the telescope. The very time-consuming and difficult tasks of designing the pulse counters, timers, clocks, data handling and data recording systems, have been essentially completed and the actual construction of this system has been started and can proceed very rapidly. The very simple data equipment built last year, and which will be incorporated in the final system discussed above, has been in regular use for all kinds of photoelectric observations for nearly a year. It has been found to be very efficient and has demonstrated that such systems can improve greatly the rate at which data can be acquired with a large telescope. As an example this system is being used in conjunction with the prime focus scanner to study faint quasi-stellar radio sources. Extensive data on six quasi-stellar radio sources have been obtained during the last year and will be published very shortly by Oke. Limited data for 3C 286 has already been published ("The Red Shift of the Quasi-Stellar Radio Source 3C 286", Astrophysical Journal, 142, 810, 1965).

The 100-inch Coudé Scanner

During the last six months the coudé scanner was converted from the rather inefficient synchronous scanning and D.C. amplifier ratio system to a versatile, all digital control system with photon counting detectors and digital readout. During the report period this instrument was used during approximately 50 percent of the 100-inch observing time. Principle users have been Drs. Münch, Oke, Vaughn, Zirin, Kuhi, and Lasker. The concept of using pulse counters for ratio recording has proven its effectiveness. Regardless of the large rapid fluctuations in the light level entering the spectrograph resulting from variable seeing and guiding, the photometric noise of each measurement corresponds to the statistical noise predicted by random variations in the total number of counted pulses. The instrument can be used at all wavelengths from λ3100 to λ11,000 and with resolutions down to 0.03 Angstroms. A large part of the observing so far has been in the infrared which has until recently received little attention due to the slowness of infrared photographic emulsions. Work is being done on planets, the moon, and various kinds of stars.

Solar Instrumentation

Engineering designs and shop details have been started on a solar telescope for Dr. Zirin. It will have several optical combinations including coronagraph, Cassegrain and direct lens systems. Actual construction of this telescope will be carried out under NASA Grant NGR 05-002-034.

Prime Focus Scanner Cold Box

Plans to double the speed of the prime-focus scanner by providing a 2-channel system have been delayed pending some experimental work on photomultiplier-tube techniques. There is a good possibility that a photomultiplier can have its quantum efficiency increased significantly by rather simple means. Experiments in the next two or three months will be carried out to test the feasibility of doing so. It is unwise to proceed immediately with the 2-channel system if further speed gains can also easily be obtained.

VII. Staff and Expenditures

The current staff levels and the expenditures under Grant NsG 426 for the six-month period 1 April 1965 - 30 September 1965 are outlined in the following table, for the various activities described above. For most of the activities, the actual expenditures in this period were somewhat less than half the yearly total budgeted amounts, notably in Planetary Spectroscopy and IR Astronomy. On the other hand, some of the activities will require more than the budgeted amounts before the year is through, so that expenditures should nearly equal the total budgeted value at the end of the grant year.

ACTIVITY	PROF. STAFF	GRAD STUDENTS	ENGR. and TECH. Full	ENGR. and TECH. Part	LABOR	MATERIALS	OVERHEAD	6 MO. TOTAL	1 YR. BUDGET
I. Cosmic Rays	Neher	0	1		2,790	1,711	817	5,318	9,155
II. Cosmic Rays	Vogt Stone	3	5	5	33,838	60,991	17,832	112,661	198,000
III. Theoretical Astrophysics	Christy	0	0	1	2,687	4,014	1,340	8,041	35,225
IV. Interplanetary Fields and Plasmas	Davis Haerendel Siscoe	3	0	1	12,818	3,390	3,241	19,449	47,820
V. Infrared Astronomy	Neugebauer Leighton Ulrich	3	3	9	29,844	20,547	9,448	59,839	182,780
VI. Planetary Spectroscopy	Münch Neugebauer Ridgeway	0	0	1	5,258	6,113	2,274	13,645	100,475
VII. Astronomy Instrumentation	Dennison Rule Oke	0	2	3	12,053	25,229	5,364	42,646	148,685
VIII. Miscellaneous, General Secretarial					1,968	1,467	687	4,122	18,760
TOTAL								265,721	740,900

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J. B. Oke "The Redshift of the Quasi-Stellar Radio Source 3C 286" Astrophys. J. 142, 810 (1965)